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Glare suppression by coherence gated negation: supplementary material

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Characterization of the glare field

Calculated and experimental CGN factor

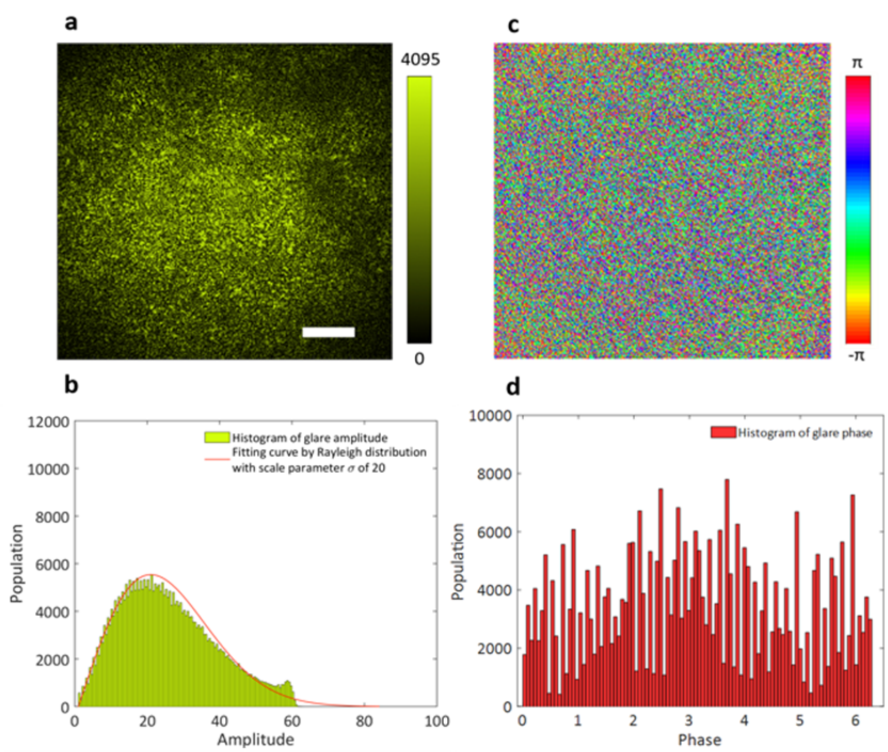

Fig. S1. Glare back-reflected from a scattering medium. (a) Intensity of the glare. The glare appears as a random speckle field. (b) Histogram of the amplitude of the glare. The amplitude of the speckle typically follows a Rayleigh distribution with probability density function $p(A) = \frac{A}{\sigma^2} e^{-\frac{A^2}{2\sigma^2}}$, where A is the amplitude and σ is the mode of the Rayleigh distribution. Fitting the data with a Rayleigh distribution (σ = 20) shows good agreement with the histogram of the measured amplitude. (c) Phase map of the glare. (d) Histogram of the phase of the glare. The phase is uniformly distributed over 0 to 2π. Scale bar is 500 μm.

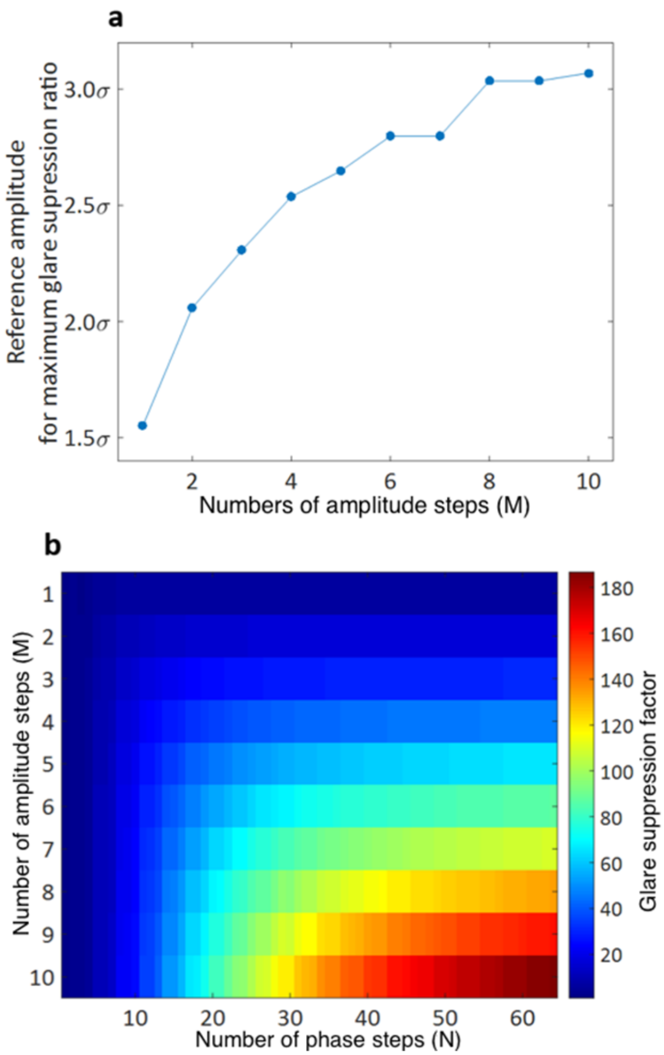

Fig. S2. Ideal glare suppression factor computed via simulation.

To simulate glare, a speckle field of 10^6 grains is generated, which follows a Rayleigh distribution in amplitude and a uniform distribution in phase. We also generate multiple sets of reference fields consisting of different numbers of steps in amplitude and phase. The number of reference fields for a single set, whose number of steps in amplitude and phase are M and N, respectively, is $M \times N$. By screening for the minimum value of destructive interference between the speckle field and the whole set of reference fields, the residue of glare of the speckle field is determined as the glare after CGN is applied. The glare suppression factor is calculated from the ratio of the glare intensity before and after CGN. Fig. S2a is a plot of the optimum reference amplitude versus the number of amplitude steps. If the reference amplitude is set to the maximum glare amplitude, the glare suppression factor will be extremely low. Due to the Rayleigh distributed amplitude, the majority of the glare amplitude values are much lower than its maximum, as shown in Fig. S1b. To efficiently suppress the glare, the reference maximum amplitude must be chosen properly. This plot can be used as a reference. Fig. S2b is a 2D plot of glare suppression factor versus the number of steps in the reference amplitude and phase. When the number of steps in amplitude and phase are 10 and 32 respectively, the ideal glare suppression factor is around 130. As a comparison, a series of glare suppression factors were measured. The experimental results are included in Fig. S3. From the plot, we can tell when the number of steps in the amplitude and phase are 10 and 32, respectively, the measured glare suppression factor is around 30. The mismatch between measured and ideal glare suppression factor can be attributed to: a) phase jitter in the reference beam and the sample beam due to vibration in the system, b) noise in the electronics including the laser and electro-optical modulator, and c) limited extinction ratio of the amplitude modulator, polarized optics, etc.

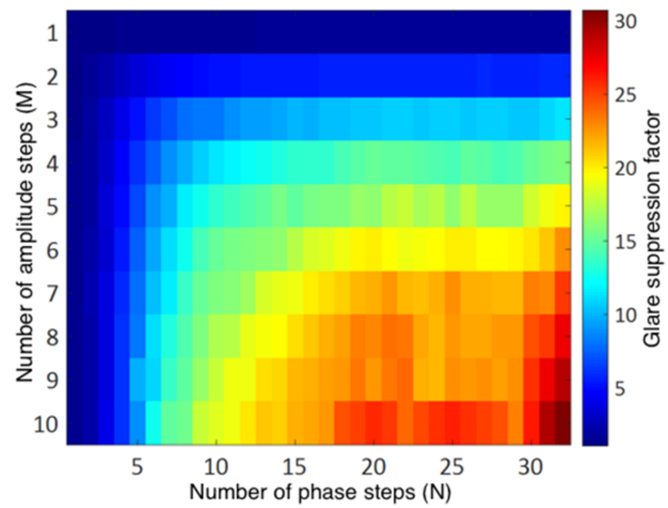

Fig. S3. Measured glare suppression factor.

Light source coherence characterization

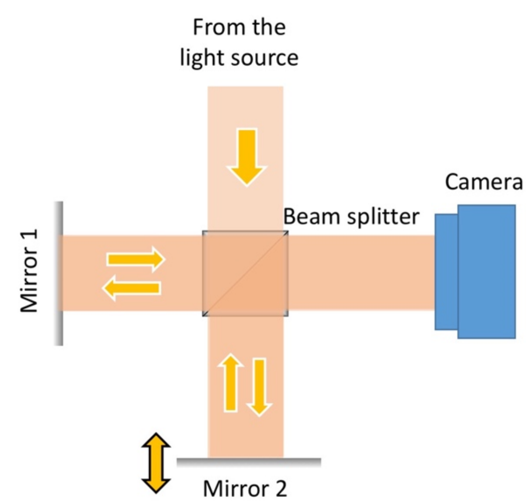

Fig. S4. Schematic setup of Michelson interferometer for characterizing the coherence properties of the light source.

To characterize the coherence of the light source, a Michelson interferometer was built as shown in Fig, S4. Collimated light from the laser was split into two arms by a beam splitter. Each of those was reflected back toward the beamsplitter which then combined their amplitudes interferometrically. The resulting interference pattern was captured by a camera (Prosilica GX 1920, Allied Vision). The two plane waves intersected with an angle, therefore parallel fringes can be observed on the camera. The contrast of the fringes ν represents the coherence of the light source,

$$\nu = \frac{I_{max}-I_{min}}{I_{max}+I_{min}} \qquad \textbf{(S1)}$$

where I_{max} is the maximum intensity of the bright fringes and I_{min} is the minimum value of the dark fringes. Mirror 2 was mounted on a piezo stage (AG-LS25, Newport). The stage traveled a distance of 5 millimeters. A series of interference patterns were captured at different positions, from which their corresponding contrasts were calculated. A plot of the contrasts versus the position were included in Fig. S5. From the plot, we can tell its full width half maximum (FWHM), which is equivalent to the coherence length, is 1.03 mm.

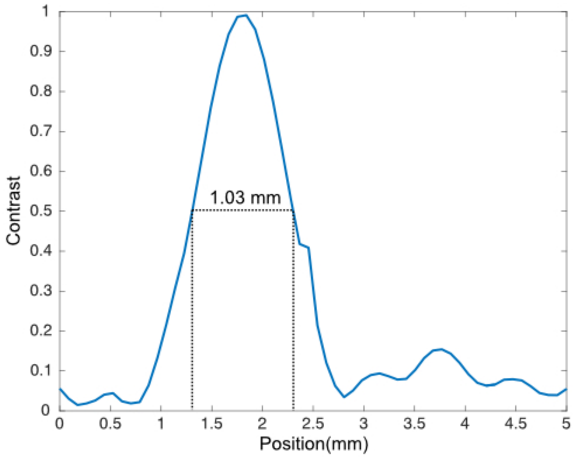

Fig. S5. Plot of fringe contrast versus mirror position.